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GENERATION OF NANOPARTICLES IN BIOLOGICAL SYSTEMS AND THEIR APPLICATION PROSPECTS

Aygun Nasibova[1,2*]

[1]Institute of Radiation Problems, Ministry of Science and Education of the Republic of Azerbaijan, Baku, Azerbaijan
[2]Department of Biophysics and Biochemistry, Baku State University, Baku, Azerbaijan

Abstract. The conducted research work is dedicated to the study of control and irradiated different doses of ionizing gamma radiation of wheat (*Triticum aestivum* L.) belonging to C3 plants and corn (*Zea mays* L.) belonging to C4 plants. Control and irradiated wheat and corn seeds with different doses were germinated in water and soil, and paramagnetic centers in their 10-day seedlings were comparatively studied. The resulting paramagnetic centers were studied by the method of Electron Paramagnetic Resonance spectroscopy. The interpretation of spectra recorded in a wide range of magnetic field (0-10000 G) showed that the effect of radiation on C3 plant wheat sprouts grown either in water or in soil leads to the formation of nanophase magnetic particles. Such result was not obtained in the corn plant, which belongs to the C4 type of photosynthesis.

Keywords: *radiation, EPR signals, magnetic nanoparticles, free radicals.*

[*]***Corresponding Author:*** *Aygun Nasibova, Department of Biophysics and Biochemistry, Baku State University, Baku, Azerbaijan; Institute of Radiation Problems, Ministry of Science and Education of the Republic of Azerbaijan, Baku, Azerbaijan, e-mail: aygunnasibova21@gmail.com*

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1. Introduction

The Absheron Peninsula (Azerbaijan) is rich in natural resources consisting of living and non-living systems. Unfortunately, in modern times, various heavy metals, radioactive pollution, toxic industrial waste, as well as the strengthening of other anthropogenic factors have a negative effect on natural components.

In addition, the pollution of soil and various water bodies in the Absheron Peninsula remains an important environmental problem due to the development of the oil and gas industry. Pollution of the environment with radioecological factors seriously endangers the health of biological systems and the living world and has an inhibitory effect on its development (Garibov *et al.*, 2008; Ahmadov *et al.*, 2009). In connection with the contamination of biological systems characteristic of the Absheron Peninsula by various stress factors (ionizing gamma radiation, radioactive contamination, UV radiation, etc.), the study of the mechanisms of the impact of these factors is of great importance. The impact of such stress factors on natural systems causes the generation of free radicals, various toxic substances, including reactive oxygen species (ROS). Due to the damaging effect of stress factors on natural systems, the changes occurring in

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them are intensively studied (Khalilov *et al.,* 2011, Nasibova *et al.,* 2021a). Studying structural-functional changes and new physico-chemical properties in Absheron's living systems affected by stress factors such as radioactive pollution, heavy metals, UV radiation, and various toxic industrial wastes is one of the important problems.

In general, many scientific-research works have been performed in the direction of studying the impact of various stress factors on the living world, and important results have been obtained in this field. However, the phenomena of paramagnetism and new physico-chemical properties that occur in biosystems characteristic of the Absheron Peninsula when exposed to various stress factors have not been studied. One of the main research methods for studying these phenomena is the Electron Paramagnetic Resonance spectroscopy method, which we have given great preference to in our research.

At the same time, research conducted in recent years has shown that living matter, from bacteria to humans, consists of natural iron oxide magnetic nanoparticles formed as a result of biomineralization processes (Khomutov, 2011; Nasibova *et al*., 2023). It is known that the most common magnetic nanoparticles in living and non-living nature are magnetite (Fe3O4) and maghemite (γ-Fe2O3). Paramagnetic centers obtained in natural systems by the EPR method allow to detect these nanoparticles (Khomutov *et al*., 2014; Nasibova *et al*., 2015; Kavetskyy *et al*., 2018). In this regard, it is very important to study the effect of stress factors on the paramagnetic centers created in natural systems, as well as to investigate the biogenic formation of nanophase crystalline magnetic structures in them as a result of biomineralization.

The presented article is dedicated to the research conducted in this field and the interpretation of the obtained results.

2. Materials and methods

In modern times, various nanomaterials and nanoparticles are synthesized by physical, chemical, and biological methods. These nanomaterials and nanoparticles are used almost in all areas of human activity, especially in medicine, environmental protection, and various industries.

Iron oxide magnetic nanoparticles (Fe3O4 - magnetite and γ-Fe2O3 - maghemite) are among the most needed nanoparticles, and can be biogenically formed in various biological systems, plants, animals, fish, insects, birds and other systems (Nasibova, 2020; Gonchalo *et al*., 2020; Mammadova *et al.,* 2022).

One of the most important methods for detecting the formation of iron oxide magnetic nanoparticles in biological systems is the EPR spectroscopy method. This method was preferred in the conducted studies.

Our research objects were wheat (*Triticum aestivum* L.) belonging to the C3 type of photosynthesis and corn (*Zea mays* L.) belonging to the C4 type. Wheat and corn seeds were irradiated with different doses of ionizing gamma radiation. Irradiation of the samples was carried out in RXUND-20000 (D=0.266 rad/sec) device.

Wheat and corn seeds were irradiated with different doses of ionizing gamma radiation. Irradiation of the samples was carried out in RXUND-20000 (D=0.266 rad/sec) device. The irradiated seeds were germinated under laboratory conditions at room temperature. 10-day-old seedlings were studied by EPR spectroscopy (BRUKER EMX, Germany). The samples were ground and placed in special quartz glass containers after drying at room temperature under natural conditions. EPR spectra of the

samples placed in the magnetic field in the resonator were recorded at room temperature, in a wide range of the magnetic field (0-10000 G).

3. Results

Control (non-irradiated) and irradiated with ionizing gamma radiation at different doses (50 Gy, 100 Gy, 300 Gy) wheat and corn seeds were germinated in water and soil at the same time in special containers. Then the paramagnetic centers in the 10-day-old seedlings of these plants were studied by the EPR method (Fig. 1 A, B and Fig. 2 A, B). Figure 1 shows the results of experiments with wheat. Here, the spectra of wheat samples irradiated with different doses of ionizing gamma radiation and germinated in water (Fig. 1A), as well as irradiated with different doses of ionizing gamma radiation and germinated in soil (Fig.1B) are shown.

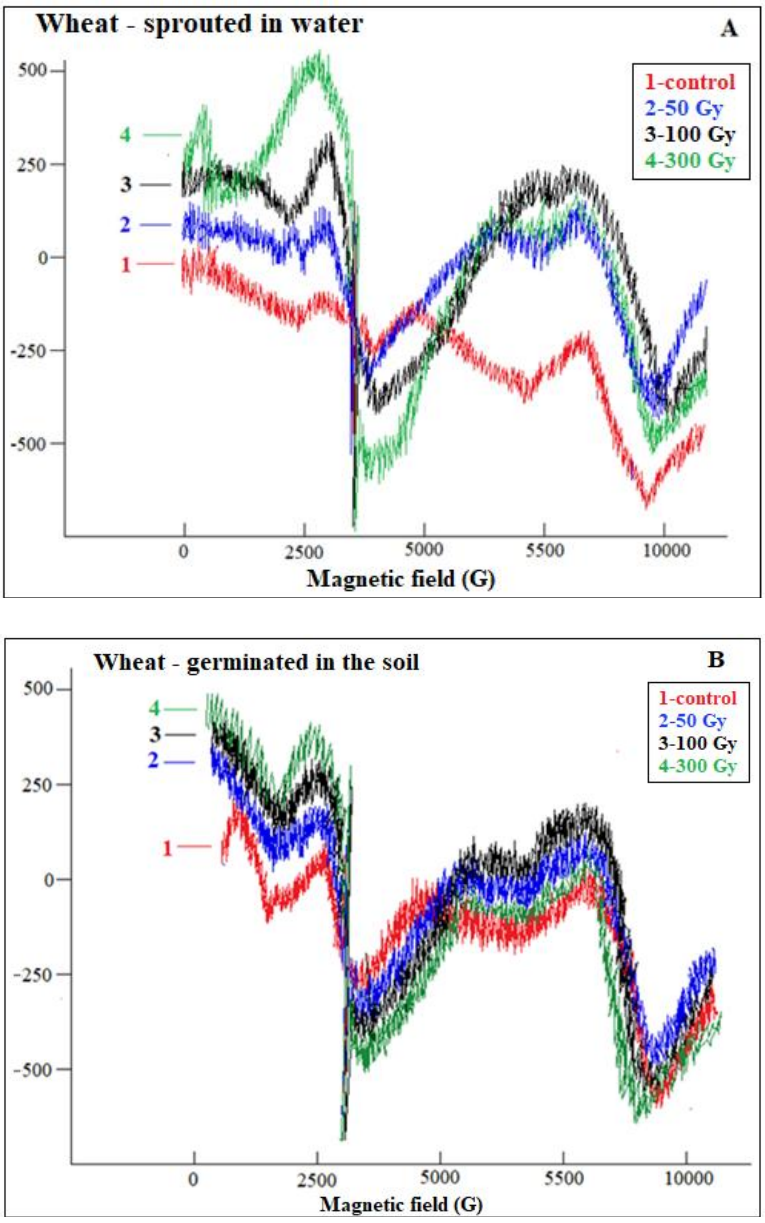

Fig. 1. EPR spectra of sprouts of irradiated at different doses wheat seeds grown in water (A) and soil (B)

Similar experiments were conducted with the corn plant. Fig. 2 shows the EPR spectra of control and irradiated with different doses of ionizing gamma radiation of sprouts of corn seeds germinated in water and soil at room temperature.

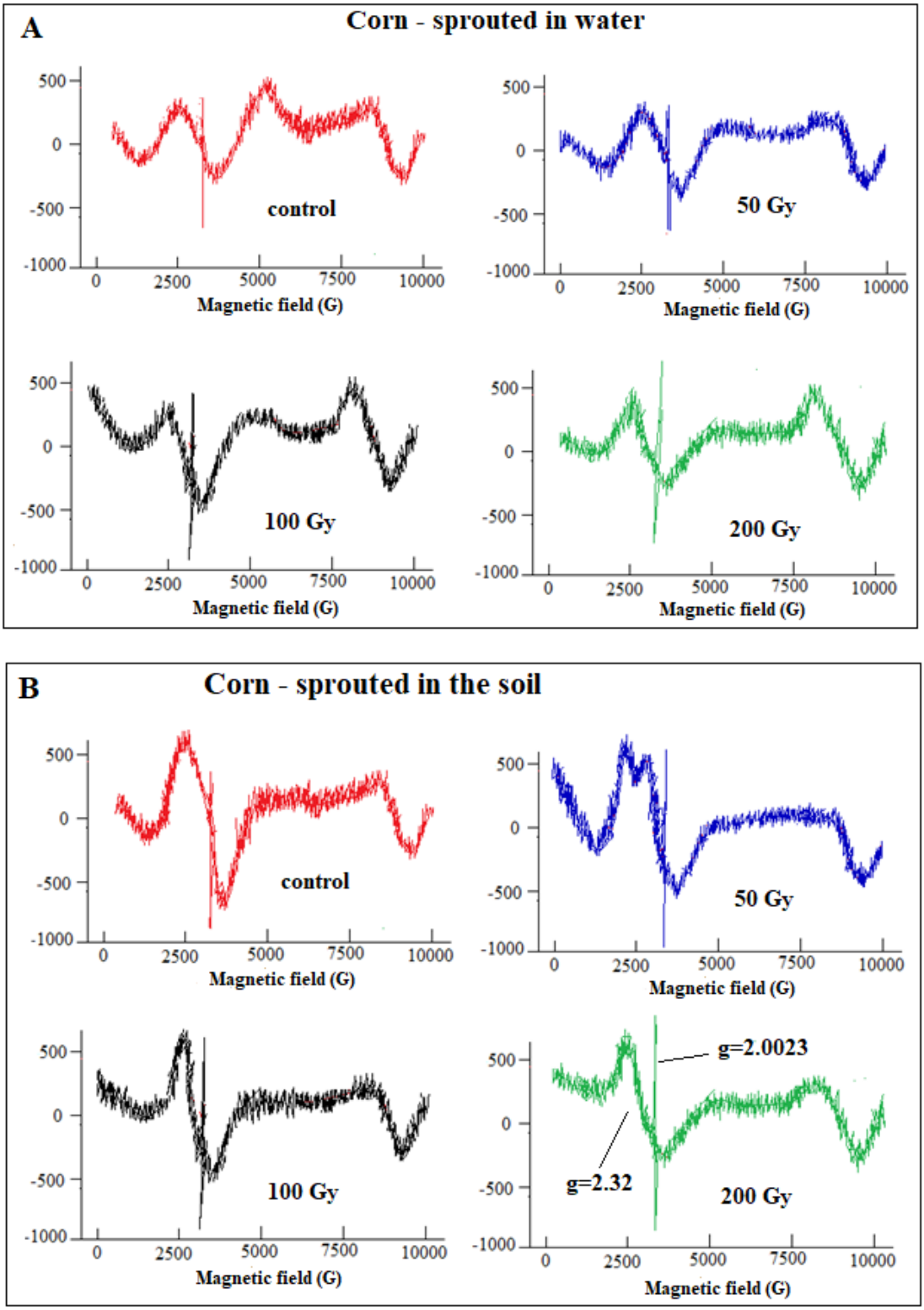

Fig. 2 EPR spectra of sprouts of irradiated at different doses corn seeds grown in water (A) and soil (B)

4. Discussion

The EPR spectra of sprouts of control (non-irradiated) and irradiated with different doses of gamma radiation wheat seeds, were recorded in a wide range of magnetic fields (0-10000 G) (Fig. 1). Signals of iron ions (g=3.4), signals characterizing iron oxide magnetic nanoparticles (g=2.3) and free radical signals (g=2.00) were recorded in the spectra given in Fig.1 (A). As can be seen from fig. 1, the increase in the dose of gamma radiation irradiation led to an increase in the intensities of the signals received from water-grown wheat sprouts. Thus, an increase in the amplitudes of both free radical signals and signals characterizing iron oxide magnetic nanoparticles was observed. An increase in the intensity of the signals with the increase of the radiation dose was also observed in the spectra obtained from the seedlings grown in the soil. However, the growth in these samples was slightly weaker than the samples grown in water.

Control and irradiated with various doses of ionizing gamma radiation, corn seeds were grown both in water and in soil, like wheat seeds. EPR spectra of 10-day-old seedlings were recorded. The results of the experiments conducted with corn belonging to C4 plants were somewhat different. In the EPR spectra of control and irradiated corn seedlings grown both in water and in soil, only changes in the intensity of free radical signals were observed. A linear increase in the intensity of the free radical signals of the irradiated samples compared to the signals of the control samples was observed with the increase of the radiation dose. However, no changes in the intensity of the signals (g=2.32) characterizing magnetic iron oxide nanoparticles were observed.

The generation of broad EPR signals characterizing iron oxide magnetic nanoparticles during stress may be related to the operation of the photosynthetic apparatus in plants (Nasibova *et al.,* 2016, 2021b; Khalilov *et al*., 2018). Based on the results, we can say that the stimulation of the formation of magnetic nanoparticles in plants may be related to the partial destruction of the integrity of chloroplasts due to the increase in the dose of stress factors (Kavetskyy *et al*., 2020; Nasibova, 2019).

5. Conclusion

The obtained results suggest that radiation has a stimulating effect on the formation of iron oxide magnetic nanoparticles in C3 plants up to a certain dose. The study of the paramagnetic centers of seedlings of control and gamma-irradiated wheat seeds (C3 plants) grown both in water and in soil shows that an increase in the irradiation dose leads to an increase in the intensity of signals characterizing magnetic iron oxide nanoparticles.

During the study of paramagnetic centers in corn sprouts (C4 plant) irradiated with gamma radiation, it was determined that the effect of radiation does not lead to the formation of nanophase magnetic particles. It is observed that only the intensity of free radical signals increase linearly under the influence of radiation. İt is observed, that only the intensity of free radical signals increases linearly under the action of radiation.

Under the influence of certain doses of ionizing gamma radiation on wheat belonging to C3 plants, the stimulating effect can manifest itself due to the activation of the photorespiration process in these plants under stress and the performance of a protective function by reducing the amount of reactive oxygen species (ROS). During stress, photorespiration in C3 type plants plays the role of a defense system by

preventing the formation of active forms of ROS. It is known that photorespiration is accelerated when too many carbohydrate products of photosynthesis are formed, and the consumption of sucrose by transport systems and acceptor organs cannot cope with their evacuation. Such conditions lead to oxidation of "excess" sugar and amino acids are formed (Chikov, 1996).

The importance and significance of the obtained result is related to the phenomenon of the formation of iron oxide magnetic nanoparticles in various living systems by biogenic means. Biogenic formation of nanophase magnetic particles is associated with a number of pathologies, including important physiological processes. Thus, in recent years, such nanoparticles have been discovered in people suffering from neurodegenerative diseases (Khomutov, 2011). The obtained results are of great importance for the development of the scientific direction related to the study of the phenomenon of biomineralization and the creation of inorganic nanophase magnetic particles in biological systems.

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